APPARATUS AND METHOD FOR MODULATING DATA MESSAGE BY EMPLOYING ORTHOGONAL VARIABLE SPREADING FACTOR (OVSF) CODES IN MOBILE COMMUNICATION SYSTEM

Field of the Invention

The present invention relates to an apparatus and method for modulating a data message in a mobile communication system; and, more particularly, to an apparatus and method for modulating a data message by employing orthogonal variable spreading factor (OVSF) codes in a mobile communication system.

Description of the Prior Art

Generally, a mobile communication system such as an international mobile telecommunication-2000 (IMT-2000) system is capable of providing various services of good quality and large capacity, an international roaming and so on. The mobile communication system can be applicable to high-speed data and multimedia services such as an Internet service and an electronic commerce service. The mobile communication system carries out orthogonal spread with respect to multiple channels. The mobile communication system allocates the orthogonal spread channels to an in-phase (I) branch and a quadrature-phase (Q) branch. A peak-to-average power ratio (PAPR) needed to simultaneously transmit I-branch data and Q-branch data affects power efficiency of a mobile station and a battery usage time of the mobile station.

The power efficiency and the battery usage time of the mobile station are closely related to a modulation scheme of the mobile station. As a modulation standard of IS-2000 and asynchronous wideband-CDMA, the modulation scheme of orthogonal complex quadrature phase shift keying (OCQPSK) has been adopted. The modulation scheme of OCQPSK is disclosed in an article by JaeRyong Shim and SeungChan Bang: *'Spectrally Efficient Modulation and Spreading Scheme for CDMA Systems' in electronics letters*, 12th November 1998, vol. 34, No. 23, pp. 2210-2211.

As disclosed in the article, the mobile station carries out the orthogonal spread by employing a Hadamard sequence as a Walsh code in the modulation scheme of the OCQPSK. After the orthogonal spread, I and Q channels are spread by a Walsh rotator and a spreading code, e.g., a pseudo noise (PN) code, a Kasami code, a Gold code and so on.

Further, as for multiple channels, the mobile station carries out the orthogonal spread by employing different Hardamard sequences. After the orthogonal spread, the orthogonal spread channels are coupled to I and Q branches. Then, the orthogonal spread channels coupled to the I branch and the orthogonal spread channels coupled to the Q branch is separately summed. The I and Q branches are scrambled by the Walsh rotator and the scrambling code. However, there is a problem that the above-mentioned modulation scheme can not effectively reduce the PAPR in the mobile communication system.

Summary of the Invention

It is, therefore, an object of the present invention to provide an apparatus and method for modulating a data message that is capable of improving a power efficiency of a mobile station by reducing a peak-to-average power ratio in a mobile communication system.

In accordance with an embodiment of an aspect of the present invention, there is provided an apparatus for converting source data to a channel- modulated signal having a plurality of pairs of in-phase (I) and quadrature-phase (Q) data in a mobile station, wherein the mobile station uses at least one channel, comprising: channel coding means for encoding the source data to generate at least one data part and a control part; code generating means for generating at least one spreading code to be allocated to the channel, wherein each spreading code is selected on the basis of a data rate of the data part and the control part and spreading codes are selected so that two consecutive pairs of the I and Q data are correspondent to two points located on same point or symmetrical with respect to a zero point on a phase domain; and spreading means for spreading the control part and the data part by using the spreading code, to thereby generate the channel-modulated signal.

In accordance with another embodiment of the aspect of the present invention, there is provided an apparatus for converting source data to a channel-modulated signal having a plurality of pairs of in-phase (I) and quadrature-phase (Q) data in a mobile station, wherein the mobile station uses N number of channels where N is a positive integer, comprising: channel coding means for encoding the

source data to generate (N-1) number of data parts and a control part; code generating means for generating N number of spreading codes to be allocated to the channels, wherein each spreading code is selected on the basis of a data rate of each data part and the control part and the spreading codes are selected so that two consecutive pairs of the I and Q data are correspondent to two points located on same point or symmetrical with respect to a zero point on a phase domain; and spreading means for spreading the control part and the data parts by using the spreading codes, to thereby generate the channel-modulated signal.

In accordance with an embodiment of another aspect of the present invention, there is provided a mobile station for converting source data to a channel-modulated signal having a plurality of pairs of in-phase (I) and quadrature-phase (Q) data, wherein the mobile station uses N number of channels where N is a positive integer, comprising: channel coding means for encoding the source data to generate (N-1) number of data parts and a control part; code generating means for generating N number of spreading codes to be allocated to the first and the second channels, wherein each spreading code is selected on the basis of a data rate of each data part and the control part and the spreading codes are selected so that two consecutive pairs of the I and Q data are correspondent to two points located on same point or symmetrical with respect to a zero point on a phase domain; and spreading means for spreading the control part and the data parts by using the spreading codes, to thereby generate the channel-modulated signal.

In accordance with an embodiment of further another aspect of

the present invention, there is provided a method for converting source data to a channel- modulated signal having a plurality of pairs of in-phase (I) and quadrature-phase (Q) data in a mobile station, wherein the mobile station uses at least one channel, comprising the steps of: a) encoding the source data to generate at least one data part and a control part; b) generating at least one spreading code to be allocated to the channel, wherein each spreading code is selected on the basis of a data rate of the data part and the control part and spreading codes are selected so that two consecutive pairs of the I and Q data are correspondent to two points located on same point or symmetrical with respect to a zero point on a phase domain; and c) spreading the control part and the data part by using the spreading code, to thereby generate the channel-modulated signal.

In accordance with another embodiment of further another aspect of the present invention, there is provided a method for converting source data to a channel- modulated signal having a plurality of pairs of in-phase (I) and quadrature-phase (Q) data in a mobile station, wherein the mobile station uses N number of channels where N is a positive integer, comprising: a) encoding the source data to generate (N-1) number of data parts and a control part; b) generating N number of spreading codes to be allocated to the channels, wherein each spreading code is selected on the basis of a data rate of each data part and the control part and the spreading codes are selected so that two consecutive pairs of the I and Q data are correspondent to two points located on same point or symmetrical with respect to a zero point on a phase domain; and c) spreading the control part and the data parts by using the spreading codes, to thereby generate the

channel-modulated signal.

Brief Description of the Drawings

The above and other objects and features of the instant invention will become apparent from the following description of preferred embodiments taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram illustrating a mobile station to which the present invention is applied;

Fig. 2 is an exemplary view illustrating a tree structure of spreading codes applied to the present invention;

Fig. 3 is an exemplary block diagram depicting a modulator shown in Fig. 1 in accordance with the present invention;

Fig. 4 is a block diagram describing a spreading code generator shown in Fig. 3;

Fig. 5 is an exemplary diagram illustrating a case where a mobile station uses two channels;

Fig. 6 is an exemplary diagram depicting a case where multiple mobile stations share a common complex-valued scrambling code;

Fig. 7 is an exemplary diagram showing a case where a mobile station uses multiple channels;

Fig. 8 is a first exemplary view describing a desirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips;

Fig. 9 is a second exemplary view showing a desirable phase difference between rotated points on a phase domain where a Walsh

rotator rotates points at consecutive chips;

Fig. 10 is a first exemplary view depicting an undesirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips;

Figs. 11 and 12 are third exemplary views illustrating a desirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips;

Figs. 13 and 14 are second exemplary views illustrating an undesirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips;

Fig. 15 is a graphical diagram describing the probability of peak power to average power; and

Figs. 16 to 22 are flowcharts illustrating a method for modulating a data message in a mobile station in accordance with the present invention.

Detailed Description of the Invention

Referring to Fig. 1, there is shown a block diagram illustrating a mobile station to which the present invention is applied. As shown, the mobile station includes a user interface 20, a central processing unit (CPU) 180, a modem 12, a source codec 30, a frequency converter 80, a user identification module 50 and an antenna 70. The modem 12 includes a channel codec 13, a modulator 100 and a demodulator 120. The channel codec 13 includes an encoder 110 and a decoder 127.

The user interface 20 includes a display, a keypad and so on. The user interface 20, coupled to the CPU 180, generates a data

message in response to a user input from a user. The user interface 20 sends the data message to the CPU 180.

The user identification module 50, coupled to the CPU 180, sends user identification information as a data message to the CPU 180. The source codec 30, coupled to the CPU 180 and the modem 12, encodes source data, e.g., video, voice and so on, to generate the encoded source data as a data message. Then, the source codec 30 sends the encoded source data as the data message to the CPU 180 or the modem 12. Further, the source codec 30 decodes the data message from the CPU 180 or the modem 12 to generate the source data, e.g., video, voice and so on. Then, the source codec 30 sends the source data to the CPU 180.

The encoder 110, contained in the channel codec 13, encodes the data message from the CPU 180 or the source codec 30 to generate one or more data parts. Then, the encoder 110 generates a control part. The encoder 110 sends the one or more data parts to the modulator 100. The modulator 100 modulates the one or more data parts and the control part to generate I and Q signals as baseband signals. The frequency converter 80 converts the baseband signals to intermediate frequency (IF) signals in response to a conversion control signal from the CPU 180. After converting the baseband signals to the IF signals, the frequency converter 80 converts the IF signals to radio frequency (RF) signals. The frequency converter 80 sends the RF signals to the antenna 70. Further, the frequency converter 80 controls a gain of the RF signals. The antenna 70 sends the RF signals to a base station (not shown).

The antenna 70 sends the RF signals from the base station to

the frequency converter 80. The frequency converter 80 converts the RF signals to the IF signals. After converting the RF signals to the IF signals, the frequency converter 80 converts the IF signals to the baseband signals as the I and Q signals. The demodulator 90 demodulates the I and Q signals to generate the one or more data parts and the control part. The decoder 127, contained in the channel codec 13, decodes the one or more data parts and the control part to generate the data message. The decoder 127 sends the data message to the CPU 180 or the source codec 30.

Referring to Fig. 2, there is shown an exemplary view illustrating a tree structure of spreading codes as orthogonal variable spreading factor (OVSF) codes applied to the present invention. As shown, a spreading code is determined by a spreading factor (SF) and a code number in a code tree, wherein the spreading code is represented by $C_{SF,\ code\ number}$. $C_{SF,\ code\ number}$ is made up of a real-valued sequence. The SF is 2^N where N is 0 to 8, and the code number is 0 to $2^N - 1$.

$$\begin{bmatrix} C_{2,0} \\ C_{2,1} \end{bmatrix} = \begin{bmatrix} C_{1,0} & C_{1,0} \\ C_{1,0} & -C_{1,0} \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \text{ where } C_{1,0} = 1 \qquad \text{Eq. (1)}$$

$$\begin{bmatrix} C_{2^{(N+1)},0} \\ C_{2^{(N+1)},1} \\ C_{2^{(N+1)},2} \\ C_{2^{(N+1)},3} \\ \cdot \\ \cdot \\ \cdot \\ C_{2^{(N+1)},2^{(N+1)}-2} \\ C_{2^{(N+1)},2^{(N+1)}-1} \end{bmatrix} = \begin{bmatrix} C_{2^N,0} & C_{2^N,0} \\ C_{2^N,0} & -C_{2^N,0} \\ C_{2^N,1} & C_{2^N,1} \\ C_{2^N,1} & -C_{2^N,1} \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ C_{2^N,2^N-1} & C_{2^N,2^N-1} \\ C_{2^N,2^N-1} & -C_{2^N,2^N-1} \end{bmatrix} \quad \text{where N is 1 to 7} \qquad \text{Eq. (2)}$$

For example, a spreading code having an SF of 8 and a code number of 1 is represented by $C_{8,1} = \{1, 1, 1, 1, -1, -1, -1, -1\}$ according to Eqs. (1) and (2). In case where the SF is more than 2, the spreading codes are grouped by two groups, including a first group and a second group according to a code number sequence. The first group includes the spreading codes with the SF and code numbers of 0 to SF/2-1 and the second group includes the spreading codes with the SF and code numbers of SF/2 to SF-1. Therefore, the number of spreading codes contained in the first group is the same as that of spreading codes contained in the second group.

Each spreading code contained in the first or second group is made up of real values. Each spreading code contained in the first or second group can be employed in an OCQPSK modulation scheme. It is preferred that a spreading code, contained in the first group, is selected for the OCQPSK modulation scheme. However, where a spreading code, contained in the second group, is multiplied by another spreading code with a minimum code number, i.e., SF/2, contained in the second group, the multiplication of the spreading codes, contained in the second group, becomes the same as a spreading

code contained in the first group. Accordingly, the multiplication of the spreading codes contained in the second group is represented by a spreading code of the first group. As a result, all the spreading codes, i.e., OVSF codes, of the first and second groups are useful for reducing the peak-to-average power ratio (PAPR) of the mobile station.

Referring to Fig. 3, there is shown a block diagram depicting a modulator shown in Fig. 1 in accordance with the present invention. The mobile communication system includes a base station and a mobile station employing a plurality of channels, wherein the mobile station includes the modulator. The channels include a control channel and one or more data channels.

The one or more data channels include a physical random access channel (PRACH), a physical common packet channel (PCPCH) and dedicated physical channel (DPCH). In a PRACH or PCPCH application, a control channel and only one data channel, i.e., PRACH or PCPCH, are coupled between the encoder 110 and the spreader 130. The DPCH includes dedicated physical data channels (DPDCHs). In a DPCH application, a dedicated physical control channel (DPCCH) as a control channel and up to six data channels, i.e., DPDCH 1 to DPDCH 5 are coupled between the encoder 110 and the spreader 130. As shown, a modulator 100 includes an encoder 110, a code generator 120, a spreader 130, a scrambler 140, a filter 150, a gain adjuster 160 and an adder 170.

The encoder 110 encodes the data message to be transmitted to the base station to generate one or more data parts. The encoder 110 generates a control part having a control information. The

encoder 110 evaluates an SF based on a data rate of the one or more data parts.

The CPU 180, coupled to the encoder 110, receives the SF related to the one or more data parts from the encoder 110. The CPU 180 produces one or more code numbers related to the one or more data parts and an SF and a code number related to the control part.

The code generator 120 includes a spreading code generator 121, a signature generator 122 and a scrambling code generator 123. The code generator 120, coupled to the CPU 180, generates spreading codes, i.e., C_{d1} to C_{dn} and C_c, a signature S and a complex-valued scrambling code. The spreading code generator 121, coupled to the CPU 180 and the spreader 130, generates the spreading codes in response to the SF and the one or more code numbers related to the one or more data parts and an SF and a code number related to the control part from the CPU 180. The spreading code generator 121 sends the spreading codes to the spreader 130.

The signature generator 122, coupled to the CPU 180 and the spreading code generator 121, generates the signature S to send the signature S to the spreading code generator 121. The scrambling code generator 123 generates the complex-valued scrambling code to send the complex-valued scrambling code to the scrambler 140.

The spreader 130 spreads the control part and the one or more data parts from the encoder 110 by the spreading codes from the code generator 120.

The scrambler 140 scrambles the complex-valued scrambling code, the one or more data parts and the control part spread by the spreader 130, thereby generating scrambled signals. The scrambler 140

includes a Walsh rotator, which is typically employed in the OCQPSK modulation scheme. The Walsh rotator rotates the one or more data parts and the control part spread by the spreader 130.

The filter 150, i.e., a root raised cosine (PRC) filter, pulse-shapes the scrambled signals to generate pulse-shaped signals. The gain adjuster 160 multiplies each of the pulse-shaped signals by the gain of each channel, thereby generating gain-adjusted signals. The adder 170 sums the gain-adjusted signals related to an I branch or the gain-adjusted signals related to a Q branch, to thereby generate a channel-modulated signal having a plurality of pairs of I and Q data in the mobile station.

Referring to Fig. 4, there is shown a block diagram describing a spreading code generator shown in Fig. 3. As shown, the spreading code generator includes a storage device 210, an 8-bit counter 220, a plurality of logical operators 231 and 233 and a plurality of multiplexers 232 and 234.

The storage device 210 includes one or more registers 211 related to the one or more data parts and a register 212 related to the control part. The one or more registers 211 stores an SF and code numbers related to the one or more data parts sent from the CPU 180 shown in Fig. 3. The register 212 stores an SF and a code number related to the control part sent from the CPU 180.

The 8-bit counter 220 consecutively produces a count value of $B_7B_6B_5B_4B_3B_2B_1B_0$ as 8-bit count value in synchronization with a clock signal CHIP_CLK issued from an external circuit, wherein B_0 to B_7 are made up of a binary value of 0 or 1, respectively.

The one or more logical operators 231 carry out one or more

logical operations with the SF and the code numbers related to the one or more data parts stored in the one or more register 211, thereby generating the spreading codes related to the one or more data parts. A code number is represented by $I_7I_6I_5I_4I_3I_2I_1I_0$, wherein I_0 to I_7 are the binary value of 0 or 1, respectively.

The logical operator 233 carries out a logical operation with the SF and the code number of $I_7I_6I_5I_4I_3I_2I_1I_0$ related to the control part stored in the register 212, thereby generating a spreading code related to the control part.

$$\prod_{i=0}^{N-2}{}^{\oplus} I_i \bullet B_{N-1-i} \quad \text{where } 2 \le N \le 8 \qquad \text{Eq. (3)}$$

where "•" denotes a multiplication in modulo 2 and $\Pi^{\oplus}$ denotes an exclusive OR operation. Each logical operator 231 or 233 carries out a logical operation according to Eq. (3) where SF = 2^N.

If the SF is 256, each logical operator 231 or 233 carries out a logical operation of $B_7 \bullet I_0 \oplus B_6 \bullet I_1 \oplus B_5 \bullet I_2 \oplus B_4 \bullet I_3 \oplus B_3 \bullet I_4 \oplus B_2 \bullet I_5 \oplus B_1 \bullet I_6 \oplus B_0 \bullet I_7$

If the SF is 128, each logical operator 231 or 233 carries out a logical operation of $B_6 \bullet I_0 \oplus B_5 \bullet I_1 \oplus B_4 \bullet I_2 \oplus B_3 \bullet I_3 \oplus B_2 \bullet I_4 \oplus B_1 \bullet I_5 \oplus B_0 \bullet I_6$.

If the SF is 64, each logical operator 231 or 233 carries out a logical operation of $B_5 \bullet I_0 \oplus B_4 \bullet I_1 \oplus B_3 \bullet I_2 \oplus B_2 \bullet I_3 \oplus B_1 \bullet I_4 \oplus B_0 \bullet I_5$.

If the SF is 32, each logical operator 231 or 233 carries out a logical operation of $B_4 \bullet I_0 \oplus B_3 \bullet I_1 \oplus B_2 \bullet I_2 \oplus B_1 \bullet I_3 \oplus B_0 \bullet I_4$.

If the SF is 16, each logical operator 231 or 233 carries out a logical operation of $B_3 \bullet I_0 \oplus B_2 \bullet I_1 \oplus B_1 \bullet I_2 \oplus B_0 \bullet I_3$.

If the SF is 8, each logical operator 231 or 233 carries out a logical operation of $B_2 \bullet I_0 \oplus B_1 \bullet I_1 \oplus B_0 \bullet I_2$.

If the SF is 4, each logical operator 231 or 233 carries out a logical operation of $B_1 \cdot I_0 \oplus B_0 \cdot I_1$.

The one or more multiplexers 232 selectively output the one or more spreading codes from the one or more logical operators 231 in response to one or more select signals as the SF related to the one or more data parts.

The multiplexer 234 selectively outputs the spreading code from the logical operator 233 in response to a select signal as the SF related to the control part.

Referring to Fig. 5, there is shown an exemplary diagram illustrating a case where a mobile station uses two channels.

As shown, when the mobile station uses the two channels and SF = 2^N where N = 2 to 8, the spreading code generator 121 generates a spreading code of $C_{SF, SF/4}$ to be allocated to the DPDCH or the PCPCH as a data channel. Further, the spreading code generator 121 generates a spreading code of $C_{256, 0}$ to be allocated to the DPCCH or the control channel. Then, the spreader 130 spreads the DPDCH or the PCPCH by the spreading code of $C_{SF, SF/4}$. Further, The spreader 130 spreads the control channel by the spreading code of $C_{256, 0}$. At this time, the scrambling code generator 123 generates a complex-valued scrambling code assigned to the mobile station. Further, the complex-valued scrambling code can be temporarily reserved in the mobile station.

Referring to Fig. 6, there is shown an exemplary diagram depicting a case where multiple mobile stations share a common complex-valued scrambling code in the PRACH application.

As shown, where the multiple mobile stations share a common

complex-valued scrambling code and $SF = 2^N$ where N = 5 to 8 and S = 1 to 16, the spreading code generator 121 generates a spreading code of $C_{SF,\ SF(S-1)/16}$ to be allocated to the PRACH. Further, the spreading code generator 121 generates a spreading code of $C_{256,\ 16(S-1)+15}$ to be allocated to the control channel.

Then, the spreader 130 spreads the PRACH by the spreading code of $C_{SF,\ SF(S-1)/16}$. Also, the spreader 130 spreads the control channel by the spreading code of $C_{256,\ 16(S-1)+15}$. At this time, the scrambling code generator 123 generates a common complex-valued scrambling code.

Referring to Fig. 7, there is shown an exemplary diagram showing a case where a mobile station uses multiple channels. As shown, where the mobile station uses one control channel and two data channels and the SF related to the two data channels is 4, the spreading code generator 121 generates a spreading code of $C_{256,\ 0}$ to be allocated to the DPCCH. Further, the spreading code generator 121 generates a spreading code of $C_{4,\ 1}$ allocated to the DPDCH 1. Furthermore, the spreading code generator 121 generates a spreading code of $C_{4,\ 1}$ allocated to the DPDCH 2.

Then, the spreader 130 spreads the DPDCH 1 by the spreading code of $C_{4,\ 1}$. Further, the spreader 130 spreads the DPDCH 2 by the spreading code of $C_{4,\ 1}$. Furthermore, the spreader 130 spreads the DPCCH by the spreading code of $C_{256,\ 0}$. At this time, the scrambling code generator 123 generates a complex-valued scrambling codes assigned to the mobile station.

As shown, where the mobile station uses one control channel and three data channels and the SF related to the three data channels

is 4, the spreading code generator 121 further generates a spreading code of $C_{4,3}$ to be allocated to the DPDCH 3. Then, the spreader 130 further spreads the DPDCH 3 by the spreading code of $C_{4,3}$.

As shown, where the mobile station uses one control channel and four data channels and the SF related to the four data channels is 4, the spreading code generator 121 further generates a spreading code of $C_{4,3}$ to be allocated to the DPDCH 4. Then, the spreader 130 further spreads the DPDCH 4 by the spreading code of $C_{4,3}$.

As shown, where the mobile station uses one control channel and five data channels and the SF related to the five data channels is 4, the spreading code generator 121 further generates a spreading code of $C_{4,2}$ to be allocated to the DPDCH 5. Then, the spreader 130 further spreads the DPDCH 5 by the spreading code of $C_{4,2}$.

As shown, where the two mobile station uses one control channel and six data channels and the SF related to the six data channels is 4, the spreading code generator 121 further generates a spreading code of $C_{4,2}$ to be allocated to the DPDCH 6. Then, the spreader 130 further spreads the DPDCH 6 by the spreading code of $C_{4,2}$.

Referring to Fig. 8, there is shown a first exemplary view describing a desirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips.

As shown, in case where an SF is 4 and a code number is 0, a spreading code of $C_{4,0}$ is represented by {1, 1, 1, 1}. Further, in case where the SF is 4 and a code number is 1, a spreading code of $C_{4,1}$ is represented by {1, 1, -1, -1}.

Assume that two channels are spread by the spreading code of

$C_{4,0}$ = {1, 1, 1, 1} and the spreading code of $C_{4,1}$ = {1, 1, -1, -1}, respectively. At this time, real values contained in the spreading code of $C_{4,0}$ = {1, 1, 1, 1} are represented by points on a real axis of a phase domain. Further, real values contained in the spreading code of $C_{4,1}$ = {1, 1, -1, -1} are represented by points on an imaginary axis of the phase domain.

At a first or second chip, a point {1, 1}, i.e., a point ① or ②, is designated on the phase domain by first or second real values contained in the spreading codes of $C_{4,0}$ and $C_{4,1}$. At a third or fourth chip, a point {1, -1}, i.e., a point ③ or ④, is designated on the phase domain by third or fourth real values contained in the spreading codes of $C_{4,0}$ and $C_{4,1}$. The points ① and ② are positioned on the same point as each other. Also, the points ③ and ④ are positioned on the same point as each other. Where the Walsh rotator rotates the points at chips, the points are rotated by a predetermined phase, respectively.

For example, where the Walsh rotator rotates the point ① or ③ at an odd chip, the point ① or ③ is rotated to a clockwise direction by a phase of 45°. Further, where the Walsh rotator rotates the point ② or ④ at an even chip, the point ② or ④ is rotated to a counterclockwise direction by the phase of 45°. After rotating the points ① and ② or the points ③ and ④ at the odd and even chips as two consecutive chips, a phase difference between the rotated points ①′ and ②′ or the rotated points ③′ and ④′ becomes 90°. Where the phase difference between the rotated points ①′ and ②′ or the rotated points ③′ and ④′ becomes 90°, a peak-to-average power ratio (PAPR) of a mobile station can be reduced.

For another example, where the Walsh rotator rotates the point ① or ③ at an odd chip, the point ① or ③ is rotated to the counterclockwise direction by the phase of 45°. Further, where the Walsh rotator rotates the point ② or ④ at an even chip, the point ② or ④ is rotated to the clockwise direction by the phase of 45°. After rotating the points ① and ② or the points ③ and ④ at the odd and even chips as two consecutive chips, a phase difference between the rotated points ①″ and ②″ or the rotated points ③″ and ④″ becomes 90°. Where the phase difference between the rotated points ①″ and ②″ or the rotated points ③″ and ④″ becomes 90°, the peak-to-average power ratio of the mobile station can be reduced.

Referring to Fig. 9, there is shown a second exemplary view showing a desirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips.

First, assume that two channels are spread by a spreading code of $C_{4,2}$ = {1, -1, 1, -1} and a spreading code of $C_{4,3}$ = {1, -1, -1, 1}, respectively.

At a first chip, a point {1, 1}, i.e., a point ①, is designated on the phase domain by first real values contained in the spreading codes of $C_{4,2}$ and $C_{4,3}$. At a second chip, a point {-1, -1}, i.e., a point ②, is designated on the phase domain by second real values contained in the spreading codes of $C_{4,2}$ and $C_{4,3}$. The points ① and ② are symmetrical with respect to a zero point as a center point on the phase domain.

At a third chip, a point {1, -1}, i.e., a point ③, is designated on the phase domain by third real values contained in the spreading codes of $C_{4,2}$ and $C_{4,3}$. At a fourth chip, a point {-1, 1}, i.e., a

point ④, is designated on the phase domain by fourth real values contained in the spreading codes of $C_{4,2}$ and $C_{4,3}$. The points ③ and ④ are symmetrical with respect to the zero point on the phase domain. Where the Walsh rotator rotates the points at chips, the points are rotated by a predetermined phase, respectively.

For example, where the Walsh rotator rotates the point ① or ③ at an odd chip, the point ① or ③ is rotated to a clockwise direction by a phase of 45°. Further, where the Walsh rotator rotates the point ② or ④ at an even chip, the point ② or ④ is rotated to a counterclockwise direction by the phase of 45°. After rotating the points ① and ② or the points ③ and ④ at the odd and even chips as two consecutive chips, a phase difference between the rotated points ①′ and ②′ or the rotated points ③′ and ④′ becomes 90°. Where the phase difference between the rotated points ①′ and ②′ or the rotated points ③′ and ④′ becomes 90°, a peak-to-average power ratio of a mobile station can be reduced.

For another example, where the Walsh rotator rotates the point ① or ③ at an odd chip, the point ① or ③ is rotated to the counterclockwise direction by the phase of 45°. Further, where the Walsh rotator rotates the point ② or ④ at an even chip, the point ② or ④ is rotated to the clockwise direction by the phase of 45°. After rotating the points ① and ② or the points ③ and ④ at the odd and even chips as two consecutive chips, a phase difference between the rotated points ①″ and ②″ or the rotated points ③″ and ④″ becomes 90°. Where the phase difference between the rotated points ①″ and ②″ or the rotated points ③″ and ④″ becomes 90°, the peak-to-average power ratio of the mobile station can be reduced.

Referring to Fig. 10, there is shown a first exemplary view depicting an undesirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips.

First, assume that two channels are spread by the spreading code of $C_{4,0} = \{1, 1, 1, 1\}$ and the spreading code of $C_{4,2} = \{1, -1, 1, -1\}$, respectively.

At a first chip, a point {1, 1}, i.e., a point ①, is designated on the phase domain by first real values contained in the spreading codes of $C_{4,0}$ and $C_{4,2}$. At a second chip, a point {1, -1}, i.e., a point ②, is designated on the phase domain by second real values contained in the spreading codes of $C_{4,0}$ and $C_{4,2}$. The points ① and ② are symmetrical with respect to the real axis on the phase domain.

At a third chip, a point {1, 1}, i.e., a point ③, is designated on the phase domain by third real values contained in the spreading codes of $C_{4,0}$ and $C_{4,2}$. At a fourth chip, a point {1, -1}, i.e., a point ④, is designated on the phase domain by fourth real values contained in the spreading codes of $C_{4,0}$ and $C_{4,2}$. The points ③ and ④ are symmetrical with respect to the real axis on the phase domain. Where the Walsh rotator rotates the points at chips, the points are rotated by a predetermined phase, respectively.

For example, where the Walsh rotator rotates the point ① or ③ at an odd chip, the point ① or ③ is rotated to a counterclockwise direction by a phase of 45°. Further, where the Walsh rotator rotates the point ② or ④ at an even chip, the point ② or ④ is rotated to a clockwise direction by the phase of 45°. After rotating the points ① and ② or the points ③ and ④ at the odd and even chips as two

consecutive chips, a phase difference between the rotated points ①′ and ②′ or the rotated points ③′ and ④′ becomes zero. Where the phase difference between the rotated points ①′ and ②′ or the rotated points ③′ and ④′ does not become 90°, a peak-to-average power ratio of a mobile station can not be reduced.

Referring to Figs. 11 and 12, there are shown third exemplary views illustrating a desirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips.

First, assume that data of 1 allocated to a first channel is spread by a spreading code of $C_{4,1} = \{1, 1, -1, -1\}$. Further, assume that data of -1 allocated to a second channel is spread by a spreading code of $C_{4,1} = \{1, 1, -1, -1\}$. Furthermore, assume that data of 1 allocated to a third channel is spread by a spreading code of $C_{4,0} = \{1, 1, 1, 1\}$.

In terms of the first channel, the spreader 130 shown in Fig. 3 multiplies the data of 1 by the spreading code of $C_{4,1} = \{1, 1, -1, -1\}$, thereby generating a code of {1, 1, -1, -1}. Further, in terms of the second channel, the spreader 130 multiplies the data of -1 by the spreading code of $C_{4,1} = \{1, 1, -1, -1\}$, thereby generating a code of {-1, -1, 1, 1}. Furthermore, in terms of the third channel, the spreader 130 multiplies the data of 1 by the spreading code of $C_{4,0} = \{1, 1, 1, 1\}$, thereby generating a code of {1, 1, 1, 1}.

Where the spreader 130 includes an adder 131 shown in Fig. 12, the adder 131 generates a code of {0, 0, 2, 2} by adding the code of {-1, -1, 1, 1} to the code of {1, 1, 1, 1}.

Table 1

Chip	1	2	3	4
First Channel	1	1	-1	-1
Second Channel	-1	-1	1	1
Third Channel	1	1	1	1
Second channel + Third channel	0	0	2	2

Table 1 represents the spreading codes allocated to three channels and a sum of two channels depending upon chips. At a first or second chip, a point {1, 0}, i.e., a point ① or ②, is designated on the phase domain by first or second real values contained in the code of {1, 1, -1, -1} and the code of {0, 0, 2, 2}. At a third or fourth chip, a point {-1, 2}, i.e., a point ③ or ④, is designated on the phase domain by third or fourth real values contained in the code of {1, 1, -1, -1} and the code of {0, 0, 2, 2}. The points ① and ② are positioned on the same point as each other. Also, the points ③ and ④ are positioned on the same point as each other. Where the Walsh rotator rotates the points at chips, the points are rotated by a predetermined phase, respectively.

For example, where the Walsh rotator rotates the point ① or ③ at an odd chip, the point ① or ③ is rotated to a clockwise direction by a phase of 45°. Further, where the Walsh rotator rotates the point ② or ④ at an even chip, the point ② or ④ is rotated to a counterclockwise direction by the phase of 45°. After rotating the points ① and ② or the points ③ and ④ at the odd and even chips as two consecutive chips, a phase difference between the rotated points ①′ and ②′ or the rotated points ③′ and ④′ becomes 90°. Where the

phase difference between the rotated points ①′ and ②′ or the rotated points ③′ and ④′ becomes 90°, a peak-to-average power ratio of a mobile station can be reduced.

Referring to Figs. 13 and 14, there are shown second exemplary views illustrating an undesirable phase difference between rotated points on a phase domain where a Walsh rotator rotates points at consecutive chips.

First, assume that data of 1 allocated to a first channel is spread by a spreading code of $C_{4,1} = \{1, 1, -1, -1\}$. Further, assume that data of -1 allocated to a second channel is spread by a spreading code of $C_{4,2} = \{1, -1, 1, -1\}$. Furthermore, assume that data of 1 allocated to a third channel is spread by a spreading code of $C_{4,0} = \{1, 1, 1, 1\}$.

In terms of the first channel, the spreader 130 shown in Fig. 2 multiplies the data of 1 with the spreading code of $C_{4,1} = \{1, 1, -1, -1\}$, thereby generating a code of {1, 1, -1, -1}. Further, in terms of the second channel, the spreader 130 multiplies the data of -1 by the spreading code of $C_{4,2} = \{1, -1, 1, -1\}$, thereby generating a code of {-1, 1, -1, 1}. Furthermore, in terms of the third channel, the spreader 130 multiplies the data of 1 by the spreading code of $C_{4,0} = \{1, 1, 1, 1\}$, thereby generating a code of {1, 1, 1, 1}.

Where the spreader 130 includes an adder 133 shown in Fig. 14, the adder 133 generates a code of {0, 2, 0, 2} by adding the code of {-1, 1, -1, 1} to the code of {1, 1, 1, 1}.

Table 2

Chip	1	2	3	4
First Channel	1	1	-1	-1
Second Channel	-1	1	-1	1
Third Channel	1	1	1	1
Second channel + third channel	0	2	0	2

Table 2 represents the spreading codes allocated to three channels and a sum of two channels depending upon chips. At a first chip, a point {1, 0}, i.e., a point ①, is designated on the phase domain by first real values contained in the code of {1, 1, -1, -1} and the code of {0, 2, 0, 2}. At a second chip, a point {1, 2}, i.e., a point ②, is designated on the phase domain by second real values contained in the code of {1, 1, -1, -1} and the code of {0, 2, 0, 2}. At a third chip, a point {-1, 0}, i.e., a point ③, is designated on the phase domain by third real values contained in the code of {1, 1, -1, -1} and the code of {0, 2, 0, 2}. At a fourth chip, a point {-1, 2}, i.e., a point ④, is designated on the phase domain by third real values contained in the code of {1, 1, -1, -1} and the code of {0, 2, 0, 2}.

The points ① and ② or the points ③ and ④ are positioned on different points from each other. Where the Walsh rotator rotates the points at chips, the points are rotated by a predetermined phase, respectively.

For example, where the Walsh rotator rotates the point ① or ③ at an odd chip, the point ① or ③ is rotated to a clockwise direction by a phase of 45°. Further, where the Walsh rotator rotates the point ② or ④ at an even chip, the point ② or ④ is rotated to a

counterclockwise direction by the phase of 45°. After rotating the points ③ and ④ at the odd and even chips as two consecutive chips, a phase difference between the rotated points ③′ and ④′ does not become 90°. Where the phase difference between the rotated points ③′ and ④′ does not become 90°, a peak-to-average power ratio of a mobile station can increase.

Further, after rotating the points ① and ② at the odd and even chips as two consecutive chips, a phase difference between the rotated points ①′ and ②′ does not become 90°. Where the phase difference between the rotated points ①′ and ②′ does not become 90°, the peak-to-average power ratio of a mobile station can increase.

Referring to Fig. 15, there is shown an exemplary graphical diagram describing the probability of peak to average power.

When a mobile station employs two channels and spreading codes of $C_{4,0} = \{1, 1, 1, 1\}$ and $C_{4,1} = \{1, 1, -1, -1\}$ allocated to the two channels, a curve G1 is shown in the graphical diagram. At this time, the probability of the peak power exceeding the average power by 2.5 dB is approximately 1%.

Further, when a mobile station employs two channels and spreading codes of $C_{4,0} = \{1, 1, 1, 1\}$ and $C_{4,2} = \{1, -1, 1, -1\}$ allocated to the two channels, a curve G2 is shown in the graphical diagram. At this time, the probability of the peak power exceeding the average power by 2.5 dB is approximately 7%.

Referring to Fig. 16, there is shown a flowchart depicting a method for modulating a data message in a mobile station in accordance with the present invention.

As shown, at step S1302, an encoder receives a data message to

be transmitted to a base station.

At step S1304, the encoder encodes the data message having one or more data parts and generates a control part.

At step S1306, the encoder evaluates an SF related to the one or more data parts to send the SF from an encoder to a CPU.

At step S1308, the CPU produces information necessary to generate spreading codes to be allocated to channels.

At step S1310, a code generator generates the spreading codes.

At step S1312, a spreader spreads the control part and the one or more data parts by the spreading codes.

At step S1314, a scrambler scrambles the control part and the one or more data parts spread and a complex-valued scrambling code, to thereby generate a channel-modulated signal having a plurality of pairs of in-phase (I) and quadrature-phase (Q) data in the mobile station.

Referring to Figs. 17 to 19, there are flowcharts illustrative of a procedure for producing information necessary to generate spreading codes to be allocated to channels.

As shown, at step S1402, the CPU receives the SF related to the one or more data parts from the encoder.

At step S1404, the CPU determines a type of an event.

At step S1408, if the event is a case where a mobile station uses two channels, the CPU produces an SF of 256 and a code number of 0 related to the control part.

At step S1410, the CPU produces a code number of SF/4 related to the one data part where $SF = 2^N$ and $N = 2$ to 8.

At step S1412, the CPU sends the code numbers and the SFs related

to the data and control parts to the code generator.

On the other hand, at step S1414, if the event is a case where multiple mobile stations share a common complex-valued scrambling code, the CPU produces a signature S.

At step S1416, the CPU produces the SF of 256 and a code number of 16(S-1)+15 related to the control part where S = 1 to 16.

At step S1418, the CPU produces a code number of SF(S-1)/16 related to the one data part where SF = 2^N, N = 2 to 8 and S = 1 to 16.

At step S1420, the CPU sends the code numbers and the SFs related to the data and control parts to the code generator.

On the other hand, at step S1424, if the event is a case where a mobile station uses multiple channels, the CPU produces a code number of 0 and the SF of 256 related to the control part allocated to the control channel.

At step S1502, the CPU determines the number of data channels.

At step S1504, if the number of data channels is two data channels, the CPU produces a code number of 1 and an SF of 4 related to a first data part allocated to a first data channel coupled to an I branch.

At step S1506, the CPU produces a code number of 1 and the SF of 4 related to a second data part allocated to a second data channel.

On the other hand, at step S1508, if the number of data channels is three data channels, the CPU produces the code number of 1 and the SF of 4 related to the first data part allocated to the first data channel.

At step S1510, the CPU produces the code number of 1 and the SF of 4 related to the second data part allocated to the second data

channel.

At step S1512, the CPU produces a code number of 3 and the SF of 4 related to the third data part allocated to the third data channel.

On the other hand, at step S1514, if the number of data channels is four data channels, the CPU produces the code number of 1 and the SF of 4 related to the first data part allocated to the first data channel.

At step S1516, the CPU produces the code number of 1 and the SF of 4 related to the second data part allocated to the second data channel.

At step S1518, the CPU produces the code number of 3 and the SF of 4 related to the third data part allocated to the third data channel.

At step S1520, the CPU produces the code number of 3 and the SF of 4 related to a fourth data part allocated to a fourth data channel.

On the other hand, at step S1522, if the number of data channels is five data channels, the CPU produces the code number of 1 and the SF of 4 related to the first data part allocated to the first data channel.

At step S1524, the CPU produces the code number of 1 and the SF of 4 related to the second data part allocated to the second data channel.

At step S1526, the CPU produces the code number of 3 and the SF of 4 related to the third data part allocated to the third data channel.

At step S1528, the CPU produces the code number of 3 and the SF of 4 related to the fourth data part allocated to the fourth data channel.

At step S1530, the CPU produces the code number of 2 and the SF of 4 related to a fifth data part allocated to a fifth data channel.

On the other hand, at step S1532, if the number of data channels is six data channels, the CPU produces the code number of 1 and the SF of 4 related to the first data part allocated to the first data channel.

At step S1534, the CPU produces the code number of 1 and the SF of 4 related to the second data part allocated to the second data channel.

At step S1536, the CPU produces the code number of 3 and the SF of 4 related to the third data part allocated to the third data channel.

At step S1538, the CPU produces the code number of 3 and the SF of 4 related to the fourth data part allocated to the fourth data channel.

At step S1540, the CPU produces the code number of 2 and the SF of 4 related to the fifth data part allocated to the fifth data channel.

At step S1542, the CPU produces the code number of 2 and the SF of 4 related to a sixth data part allocated to a sixth data channel.

At step S1521, the CPU transmits the code numbers and the SFs related to the data and control parts to the code generator.

Referring to Fig. 20, there is shown a flowchart showing a procedure of generating the spreading codes.

As shown, at step S1702, registers receive the code numbers and the SFs from the CPU.

At step S1704, registers store the code numbers and the SFs.

At step S1706, logical operators carry out logical operations in response to an 8-bit count value, thereby generating the spreading codes.

At step S1708, multiplexers select the spreading codes in response to the SFs as select signals.

Referring to Figs. 21 and 22, there are shown flowcharts describing a procedure of carrying out the logical operations in response to the 8-bit count value, thereby generating the spreading codes.

As shown, at step S1802, each register receives a code number of $I_7I_6I_5I_4I_3I_2I_1I_0$ and a predetermined SF.

At step S1804, each register receives an 8-bit count value of $B_7B_6B_5B_4B_3B_2B_1B_0$ from an 8-bit counter.

At step S1806, a type of the predetermined SF is determined.

At step S1808, if the predetermined SF is SF_{256}, each logical operator carries out a logical operation of $B_7 \bullet I_0 \oplus B_6 \bullet I_1 \oplus B_5 \bullet I_2 \oplus B_4 \bullet I_3 \oplus B_3 \bullet I_4 \oplus B_2 \bullet I_5 \oplus B_1 \bullet I_6 \oplus B_0 \bullet I_7$.

At step S1810, if the predetermined SF is SF_{128}, each logical operator carries out a logical operation of $B_6 \bullet I_0 \oplus B_5 \bullet I_1 \oplus B_4 \bullet I_2 \oplus B_3 \bullet I_3 \oplus B_2 \bullet I_4 \oplus B_1 \bullet I_5 \oplus B_0 \bullet I_6$.

At step S1812, if the predetermined SF is SF_{64}, each logical operator carries out a logical operation of $B_5 \bullet I_0 \oplus B_4 \bullet I_1 \oplus B_3 \bullet I_2 \oplus B_2 \bullet I_3 \oplus B_1 \bullet I_4 \oplus B_0 \bullet I_5$.

At step S1814, if the predetermined SF is SF_{32}, each logical operator carries out a logical operation of $B_4 \bullet I_0 \oplus B_3 \bullet I_1 \oplus B_2 \bullet I_2 \oplus B_1 \bullet I_3 \oplus B_0 \bullet I_4$.

At step S1816, if the predetermined SF is SF_{16}, each logical operator carries out a logical operation of $B_3 \bullet I_0 \oplus B_2 \bullet I_1 \oplus B_1 \bullet I_2 \oplus B_0 \bullet I_3$.

At step S1818, if the predetermined SF is SF_8, each logical operator carries out a logical operation of $B_2 \bullet I_0 \oplus B_1 \bullet I_1 \oplus B_0 \bullet I_2$.

At step S1820, if the predetermined SF is SF_4, each logical operator carries out a logical operation of $B_1 \bullet I_0 \oplus B_0 \bullet I_1$.

At step S1822, each multiplexer generates a spreading code in response to the SF.

Although the preferred embodiments of the invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.